

## Single shot measurement of x-ray pulses using an InGaAs photodiode

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Abstract: A single x-ray pulse from APS was recorded in a manner that might be useful in single-shot diffraction studies.

Pulsed x-rays were detected in 7ID-D at an energy of 14.3 keV during a time-resolved atomic physics experiment studying the K-edge of Krypton [1]. The storage ring fill pattern was the “hybrid singlet”, consisting of a single isolated 8 mA electron bunch separated 1.59 microseconds away from a train of eight “septets”. [2] Each septet consists of seven electron bunches of ~1.7 mA current in each bunch. The spacing within a septet is 2.84 ns. This is the same spacing that each bunch will have during 1296 bunch mode, except that the single-bunch current will only be ~ 0.08 mA.

The x-ray flux measured in 7ID-B was  $1.1 \times 10^{13}$  photons/second with a white beam slit setting of 0.5 mm x 0.5 mm. X-rays were transported through an experimental setup including slits, beampipes, a vacuum chamber, windows, and a 200 mm long KB mirror pair. The photodiode measurement was taken at the end of the beamline, approximately 60 meters from the source with an x-ray flux of  $2.5 \times 10^{12}$  photons/second and a beam size of approximately 1 mm<sup>2</sup>.

The photodiode was obtained by Bernhard Adams from Judson Technologies [3], part number J22-18I-R250U1.7. The active area diameter is 250 micron. The photodiode therefore spatially overlaps approximately 5% of the available x-rays (no further information is available yet on the thickness of the absorption layer). Many different active areas are available, so it should be possible to trade off speed for sensitivity. TE cooled photodiodes are also available from this manufacturer.

The photodiode was soldered to an SMA bulkhead connector that was physically isolated from ground. The photodiode was placed into the x-ray beam using a fluorescent screen and two orthogonal picomotor stages driven remotely. A six inch long SMA flexible coax cable brought the photocurrent to a 2 GHz, 40 dB photo-receiver amplifier, HAS-Y-2-40. [4] The amplifier was powered from an isolation transformer connected to APS “clean” power. No dc bias was used for the photodiode; addition of a suitably fast dc bias might help improve rise and recovery times in the future. The amplified output was run out of the hutch by an approximately 100 foot long RG223 cable with BNC connectors.

The transient response of the photodiode was recorded by a 500 MHz, 2 Gsample/s oscilloscope (Yukogawa 7200). A trigger signal was generated from a ThorLabs DET210 Silicon GHz photo-receiver which was detecting a small fraction of an ultrafast laser pulse (50 fs, 887 Hz, 800 nm center wavelength; Coherent Legend USP-HE) which derives seed laser pulses from a homebuilt Kerr-lens modelocked Titanium:Sapphire 20

fs laser oscillator with a repetition rate of  $\sim 88$  MHz and stabilized to the x-rays with a jitter of  $< 10$  ps rms. [5]

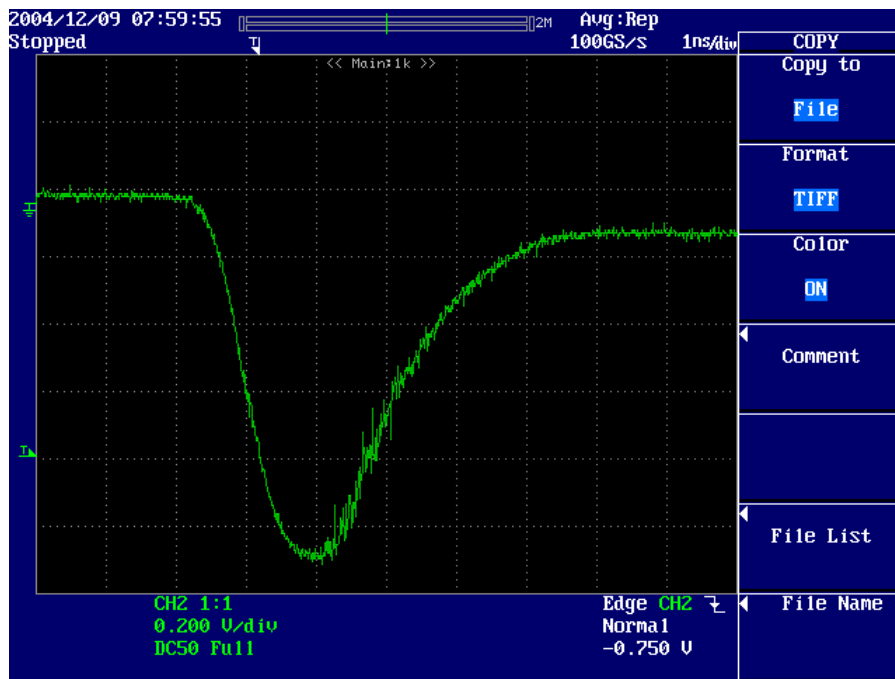


Figure 1 shows the singlet x-ray pulse exhibiting a rise time of less than 2 ns. This is an averaged, sampled oscilloscope trace.

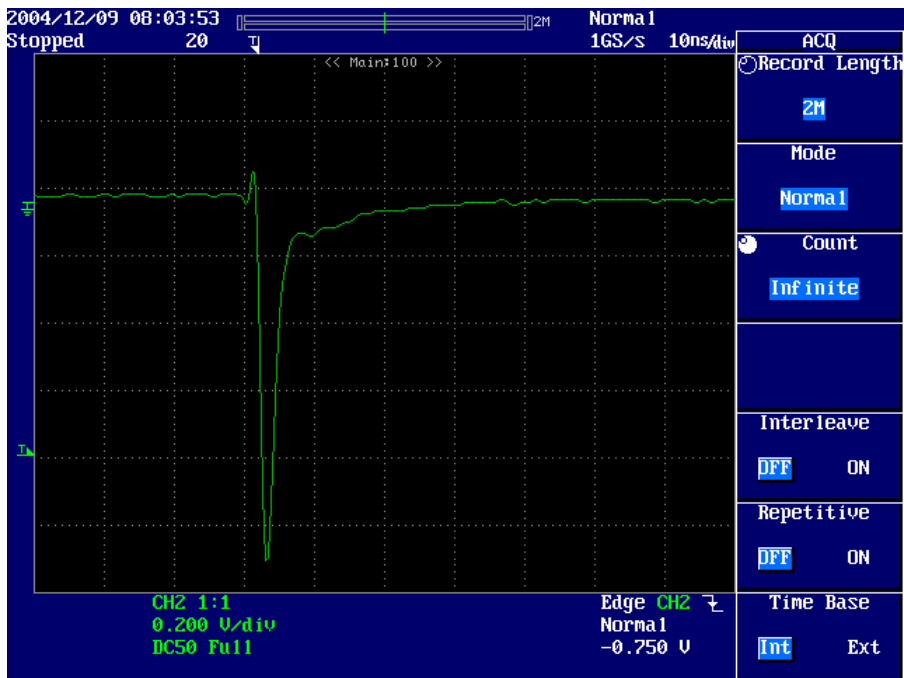


Figure 2 shows single-shot (single trigger) data from the x-ray singlet.

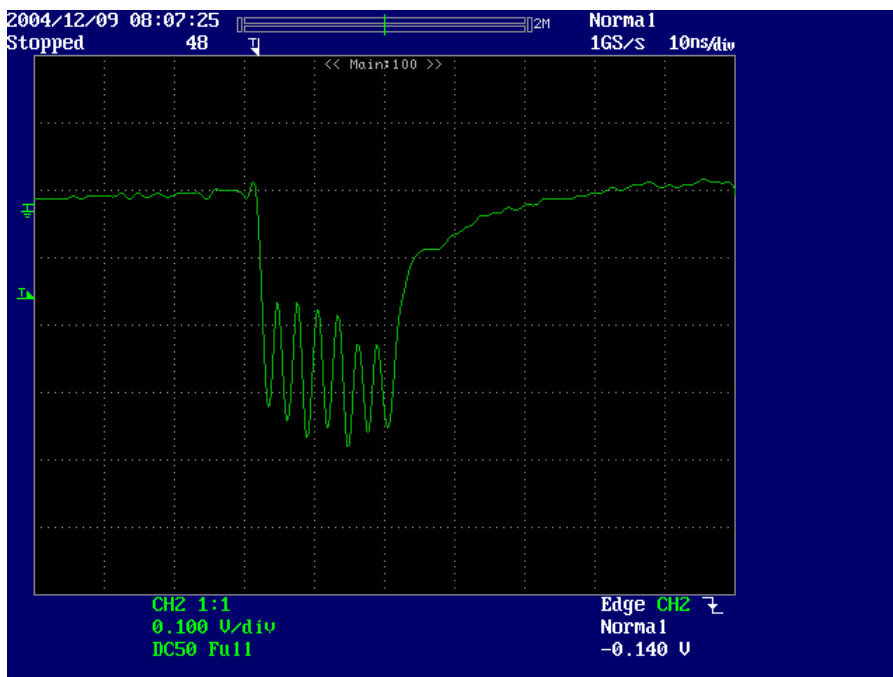


Figure 3 shows a singlet shot trace of the septet, 1.5 microseconds after the singlet. The individual x-ray bunches can be distinguished, but the detection system does not fully recover between pulses.

The linearity of the detector is demonstrated on the vertical scale of Figures 2 and 3. The septet peak 30% smaller than the singlet, which is close to the actual electron bunch charge difference.

Although the combined speed and sensitivity demonstrated here is probably not sufficient for resolving individual bunches in the new 1296 bunch mode, single shot data probably could be taken using this system in the 324 bunch mode. Improvements might make the higher fill pattern detectable on a single shot basis, including: shortening the detector to oscilloscope distance, use of a high speed dc bias, use of a higher bandwidth oscilloscope and amplifier, and proper choice of the detector area. The linearity also needs to be verified.

[1] PUP-37, "Ultrafast and Ultrasmall: Focusing on Atoms", L. Young, ANL, spokesperson

[2] APS fill patterns are described at :

[http://www.aps.anl.gov/aod/userops/Fill\\_Pattern.html](http://www.aps.anl.gov/aod/userops/Fill_Pattern.html)

[3] <http://www.judsontechnologies.com/InGaAs.htm>

[4] Product data sheet at <http://www.femto.de/datasheet/HSA-Y-2-40.pdf>

[5] D. A. Reis, M. F. DeCamp, P. H. Bucksbaum, R. Clarke, E. Dufresne, R. Merlin, "Picosecond time-resolved x-ray diffraction probe of coherent lattice dynamics," Rev. Sci. Instrum. **73** (3), March, 1361-1361 (2002).

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